No: 9/92 **Ref: EW/G92/05/34** **Category: 2c**

Aircraft Type and Registration:	Rotorway Executive, G-BPNC
No & Type of Engines:	1 Rotorway RW 152 piston engine
Year of Manufacture:	1990
Date & Time (UTC):	16 May 1992 at 1040 hrs
Location:	Quernmore, near Lancaster
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Landing gear skids distorted, tail boom fractured
Commander's Licence:	Private Pilot's Licence
Commander's Age:	30 years
Commander's Flying Experience:	180 hours (of which 91 were on type) Last 90 days - 15 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB examination of helicopter

Circumstances

The kit-built helicopter was in straight and level cruising flight at around 1100 feet above ground level with the owner/pilot and a passenger on board. The pilot heard a loud clatter and experienced heavy vibration and entered autorotation. After transmitting a Mayday call a run-on landing in a field was made, but this was heavy and both skids bent, allowing the fuselage to contact the ground. There were no injuries. The pilot believed that the aircraft was unlikely to have survived had it taken appreciably longer to reach the ground after the failure.

Owing to a misunderstanding the pilot did not report the accident until 18 June 1992. The main rotor drive system had been partially dismantled by this time.

Background

The helicopter, Serial No. 3600, was supplied in kit form by Rotorway Aircraft and constructed in the UK in early 1990. The completed aircraft was purchased by the owner/pilot involved in the accident before initial issue of the CAA Permit to Fly in the first part of 1991, and had accumulated 62 flying hours from new at the time of the accident. The last maintenance check was a 50 Hour Check conducted by the owner on 26 November 1991, 17 flying hours before the accident. At this check the split link for the drive chain was renewed in accordance with the recommendations of the kit manufacturer's Manual. No other maintenance had been carried out on the chain drive system.

The kit manufacturer was liquidated in 1990 and the assets bought by Rotorway International, which produced the Exec 90 helicopter kit, an improved version of the Exec, and continued support and parts supply for the Exec.

Chain Drive System

The secondary stage of the drive train for the main rotor comprises a small sprocket driving a triple chain that in turn drives a 16 inch diameter cast aluminium sprocket attached to the main rotor drive shaft. The sprocket axes are vertical and the drive is contained in a glass-reinforced plastic (GRP) chaincase, containing an oil bath, with a GRP cover. The large sprocket registers on the top surface of an aluminium flange bolted to the main rotor drive shaft and is attached to the flange by four ¼ inch diameter bolts on a radius of 2.15 inches (Fig 1). The bolts listed by the kit manufacturer for this application are Part No E00-2406, made from heat treated and hardened nickel steel to specification SAE-2230 with a rolled thread and cadmium plated. Each bolt is fastened by a nut with a plastic locking insert, reportedly required to be torqued to 7 lb ft, with a plain washer fitted under the nut. The bolts are fitted head down and nut up. The kit manufacturer's maintenance instructions require a check of the nut torque at 100 hour intervals. The main rotor shaft is supported by two rolling element bearings, the lower one of which is positioned just below the sprocket mounting flange and is mounted in a holder clamp incorporating an angle bracket fastened to the airframe structure. In the order of 100 shp is transmitted through the chain drive at a normal main rotor shaft speed (*ie* green arc) of 500-530 rpm. The drive system for the Rotorway International Exec 90 is the same, apart from design changes that strengthen the lower bearing mounting arrangement.

Failure

AAIB investigation showed that the drive had been running for a period with the chain displaced downwards on the large sprocket (*ie* in the axial direction of the sprocket) approximately half a tooth. In this condition the chain plates rode on the peaks of the sprocket teeth, thereby considerably increasing the radius of the arc travelled by the chain around the sprocket. Additionally, the holder clamp for the lower bearing of the main rotor drive shaft had torn away from the bracket mounting it to the airframe structure. The lower end of the main rotor shaft had moved aft before being restrained, while rotating, by contact of the shaft with the bracket. The failures in the lower bearing support all exhibited evidence of overload and were fully consistent with the effects of excessive tension in the chain resulting from the chain having ridden on the peaks of the large sprocket teeth.

One of the large sprocket attaching bolts was found fractured at a position closely corresponding with the top surface of the sprocket (*ie* the lower face of the plain washer). The normal clearance between the lower face of the flange and the chaincase would be insufficient to allow the head portion of the bolt to fall out. However, the evidence indicated that the chaincase around the large sprocket had been pushed down by the displaced chain, and distortion of the flange hole for this bolt and some marking on the chaincase showed that contact of the head with the case while the shaft had been rotating had levered the bolt out. The head portion of the bolt, the tail portion with nut attached in its normal fastened position and the plain washer had all been severely mangled, having been entrained between the chain and the sprockets. The large sprocket bore marks fully consistent with this entrainment. The small undamaged portion of the bolt fracture face exhibited signs of fatigue, and specialist inspection concluded that the bolt had failed in fast fracture fatigue that had grown from one side of the bolt and was consistent with the effects of simple bending. Evidence on the fatigue initiation and early progression was not available as these regions of the fracture surfaces had both been severely damaged after fracture.

The other three bolts were reportedly found intact with nuts in place, but no measurement of the nut torques was made before removal. One of these bolts was mislaid before AAIB investigation commenced. Inspection of the other two revealed extensive circumferential cracking in the roots of the first two or three threads nearest the shank end. After laboratory fracture of one of these bolts, specialist examination showed that the cracking had resulted from multiorigin very high cycle flexural bending fatigue. It did not extend far below the surface.

Hardness testing and micrograph evidence showed that all three bolts suffered from gross surface and sub-surface decarburisation. The degree of decarburisation found was estimated to have reduced both the static and fatigue strength of the bolts to around 50%. Typical S/N curves (stress/number of cycles) suggest that this could be consistent with a reduction from an infinite fatigue life to a life in the same order as that at which the failure occurred.

History

The only identification apparent on the bolts was 'KXP', a bolt manufacturer's designation. The aircraft builder reported that the bolts and nuts used to build the aircraft were those supplied with the kit and that he had not subsequently disturbed them. The owner reported that at no time had he disturbed the bolts or nuts.

Rotorway International reported that a number of aircraft have achieved, without sprocket bolt failure, many times the number of hours at which the bolt on G-BPNC failed, but that several failures of these bolts have occurred at a life similar to that at which the failure occurred on G-BPNC. This had been attributed to failure to correctly torque tighten the nuts on assembly.

Main rotor drive system damage somewhat similar to that occurring to G-BPNC was reported in the case of an Exec that suffered in-flight break up while in cruising flight over Quebec (C-GZRR, 10 December 1988). This was attributed to loss of chain tension.

Recommendations

The evidence showed that G-BPNC's failed bolt was severely decarburised and that this would have greatly reduced its fatigue strength, probably sufficiently to cause it to fracture under normal working loads. Having fractured, the parts of the bolt, and the nut and washer, were unrestrained and were able to fall into the chaincase. Entrainment of these parts displaced the chain, thereby causing severe chain overtensioning and consequent overload failure of the attachments for the lower bearing of the main rotor shaft. It is apparent that the failure produced a severe hazard, and that previous failures from this cause may have occurred. It is possible that a similar event to an Exec 90 could induce a different, and conceivably more severe, failure mode as the lower bearing mounting arrangement is different. Therefore the following safety recommendations are made:

92-56 It is recommended that the CAA in conjunction with the FAA require, for the Rotorway Aircraft Exec and Rotorway International Exec 90 helicopters, replacement before further flight of the bolts attaching the chain drive sprocket to the main rotor shaft flange with items that are satisfactorily quality controlled.

92-77 It is recommended that the CAA in conjunction with the FAA consider requiring, for the Rotorway Aircraft Exec and Rotorway International Exec 90 helicopters, a means of preventing the release of parts or their entrainment between the chain and sprocket in the event of failure of one or more of the bolts attaching the chain sprocket to the main rotor shaft flange.

EXPLODED VIEW OF LARGE SPROCKET ATTACHMENT

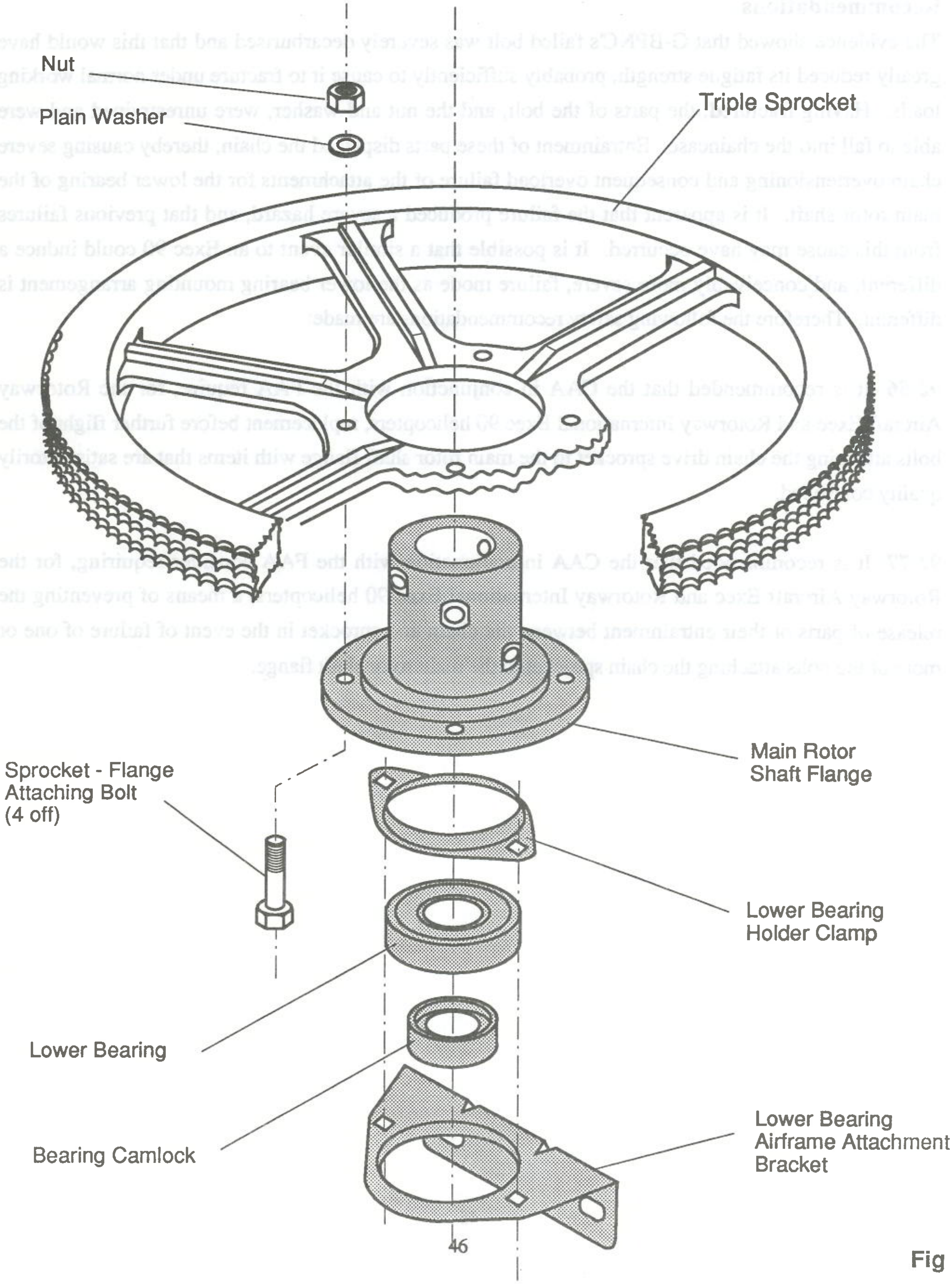

Fig 1